Opportunities for CCMC-RAL Partnership

Ian McCrea

STFC Rutherford Appleton Laboratory, Harwell, Oxford, UK

Where RAL Space fits

- Department within an institute (RAL) belonging to a UK Research Council (STFC)

- Heritage back to Radio Research Station at Slough (formed 1927)

- Space Science Department at RAL since 1980

- Department is 250 people in four divisions. Science/ operations division is ~50 people

- As a government-funded lab, providing underpinning support for the UK space science programme.

- We do commercial work, but not to make a profit. Any surplus is re-invested.

- New facilities, will be shared with UK industry

- Part of the growing "space cluster" at Harwell

Collaborations and Partnerships

- Collaborate with wide range of external stakeholders (limited internal core funding)

- STFC funded research bid competitively against other UK research groups

- Work with other UK research council (e.g. NERC, responsible for "Earth-directed" space weather)

- Work closely with UK Met Office in developing UK space weather capabilities

- UKSA and ESA are key stakeholders. UKSA is often a means for us to work on ESA projects (e.g. on science support and technology development)

- Work directly with ESA in a number of areas, including space weather. EU funding also very important.

- US collaborations are important in terms of capabilities

Science Support: STEREO

- Launched 2006, unique perspective for solar wind imaging

- UK development of the Heliospheric Imagers for the NASA STEREO mission led to thriving science support activity at RAL

- Post-launch support funded by UK Space Agency, ~ £150kpa

- Wide range of international collaborators

- Launching pad for a large number of other projects (e.g. Solar Stormwatch, HELCATS)

- Precursor to the L5 proposal....
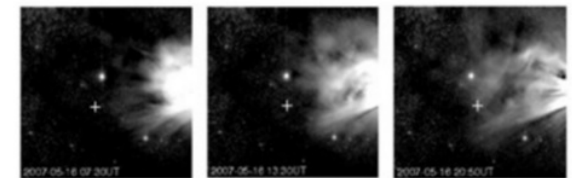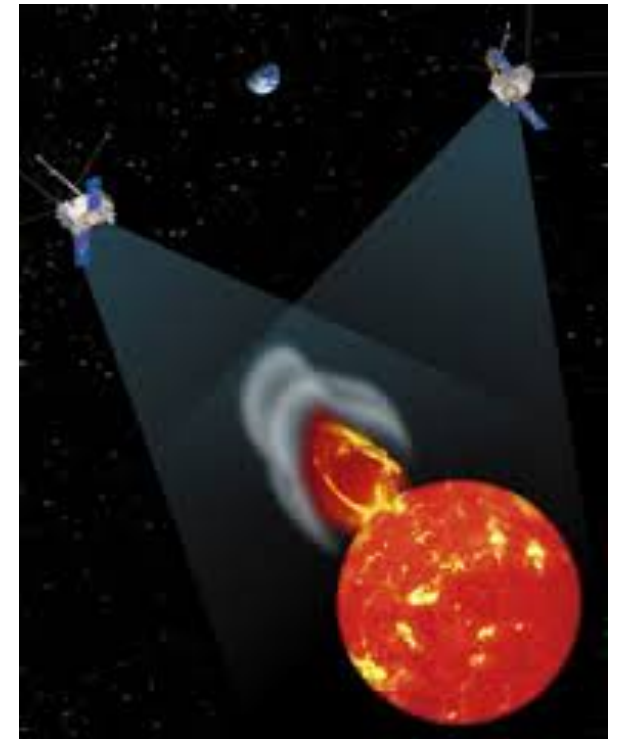
2007: HI-1A
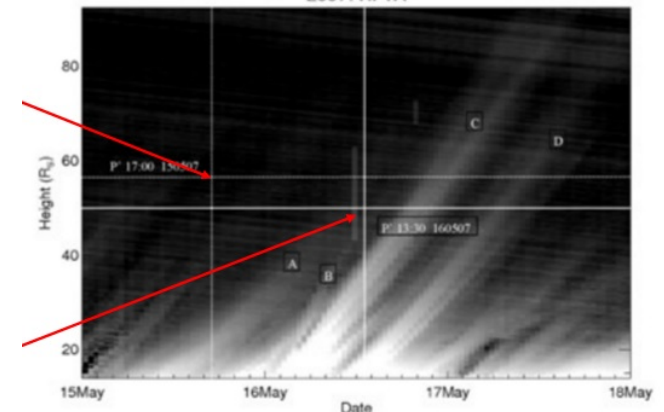
Science Support: HINODE

- JAXA mission (formerly Solar-B) launched 2006, with US and UK involvement

- Originally a three-year mission, still going strong

- UK involvement is mainly with the EIS (Extreme Ultra-Violet Imaging Spectrometer)

- RAL involvement has been in interpretation of spectroscopic measurements and cross-calibration of the spectrometer

- Based on heritage in spectroscopic data and models (ADAS)
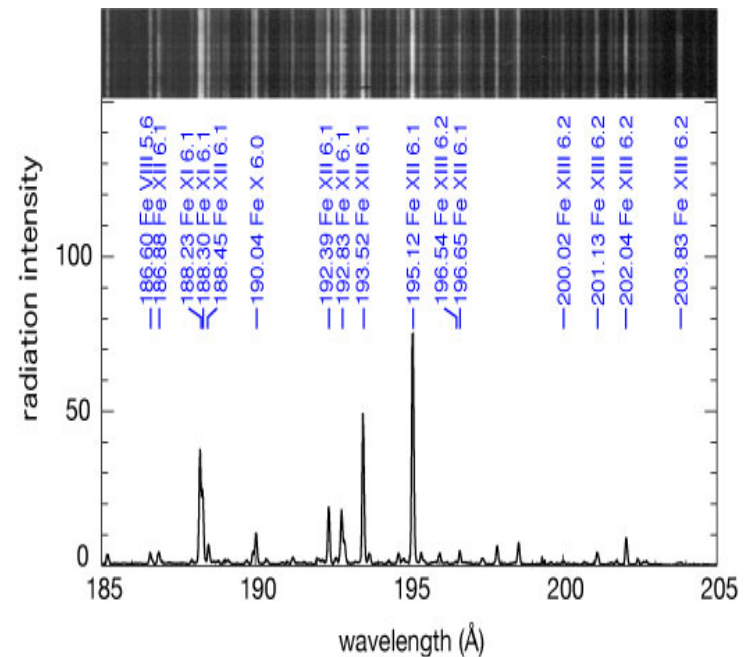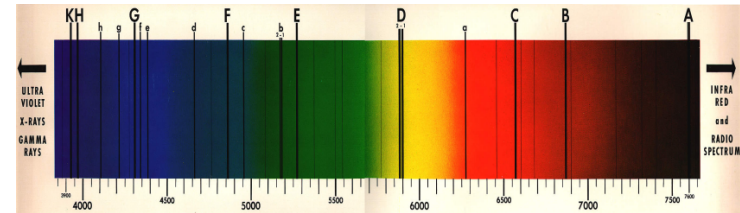
Science Support: Cluster

- In operation since 2001, mission extended to end 2016

- Further extension to 2018, seems likely, 2020 is possible

- Science expertise in multi-satellite techniques (curlometer, gradiometer) for electrodynamics

- Ground-satellite conjugate science (using EISCAT, SuperDARN etc.)

- Science support role on RAPID IES

- Work on Cluster JSOC (mission planning and commanding sequences)

- Design and deployment of Cluster Active Archive
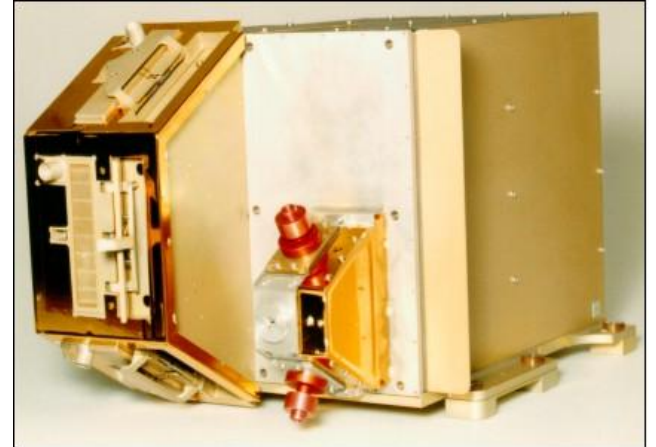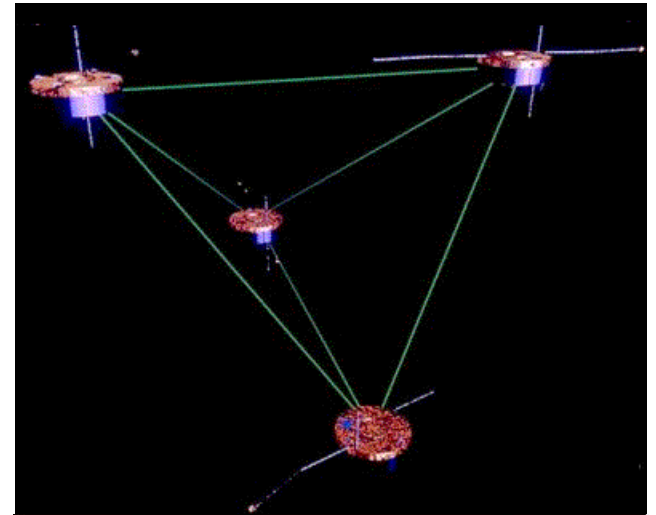
Science Support: SWARM

- Launched November 2013

- Three spacecraft for measurement of Earth's magnetic field (internal and external)

- NERC grant to study generalisation of multi-spacecraft techniques to SWARM FACs etc.

- ESA studies to prepare space weather products from SWARM data

- Particular interest in co-ordinating SWARM and Cluster conjunctions on the same field line
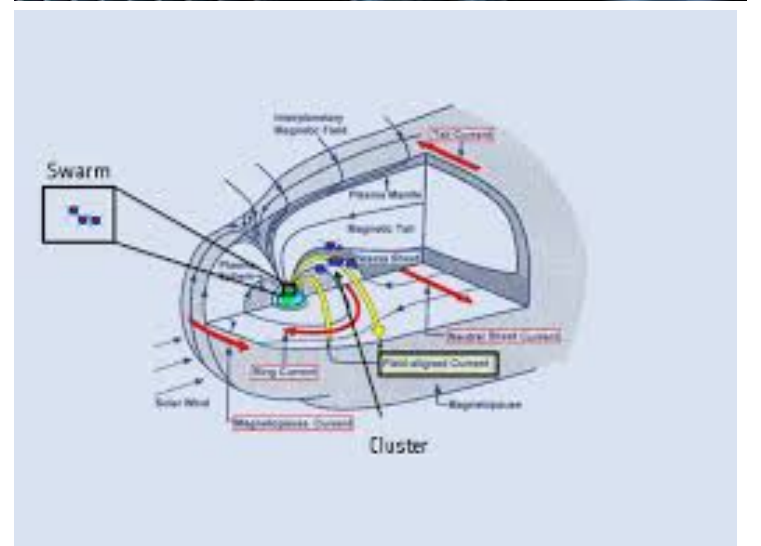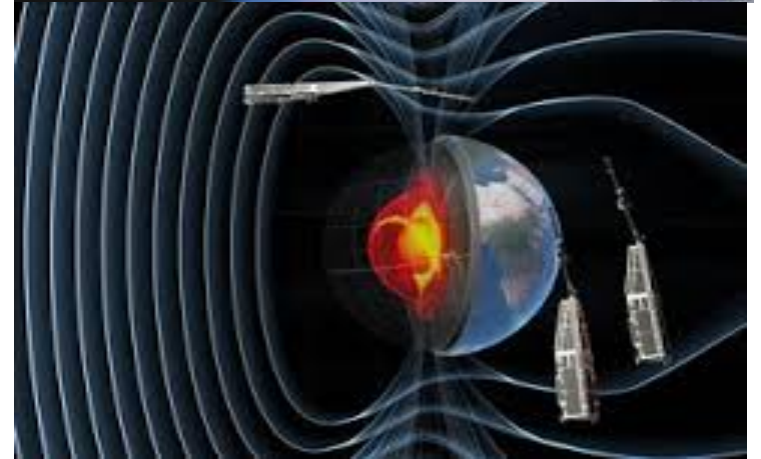
Science Support: EISCAT

- World's best ISR system, since 1981 ☺

- RAL has been UK support centre since the beginning

- Full mirror archive of all EISCAT data

- Current Chair of EISCAT Council

- Chair of URSI ISWG, responsible for setting the IS World Day schedule

- A large (and global) resource for data/model comparisons

- Now heavily involved in development and fund-raising efforts on EISCAT_3D

- 70% of capital funding already raised
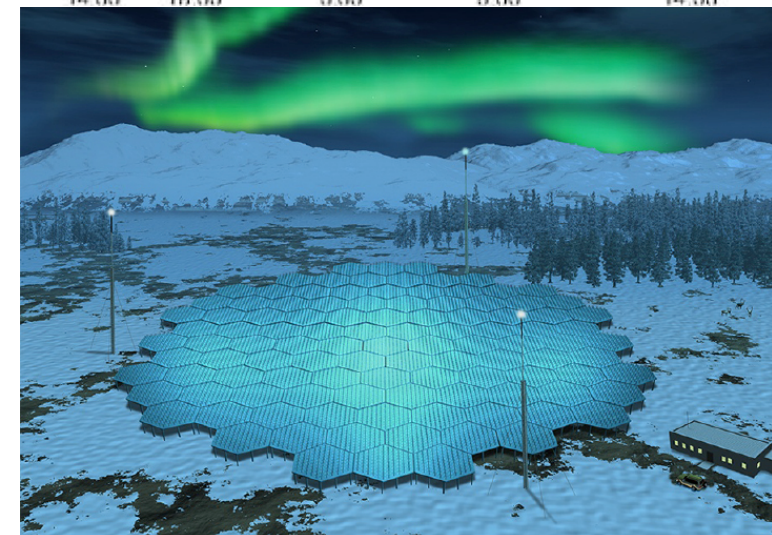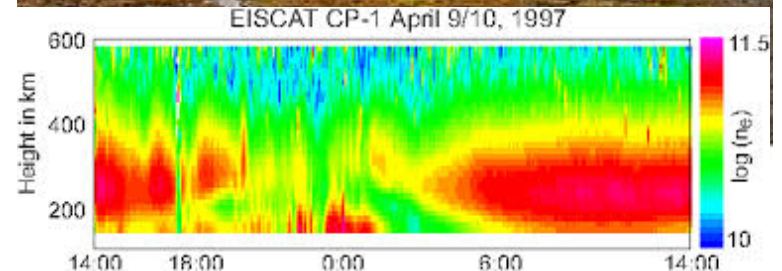
Mission Planning: Carrington (L5)

- At the heart of the planning for a potential ASEL mission with UKMO, Airbus, OHB etc.

- Working with UKMO to build political and scientific advocacy in the UK (and elsewhere)

- Discussions with NOAA and NASA too

- Using heritage on STEREO to define the benefits of an L5 mission

- Particular interests in Heliospheric Imager and Coronagraph

- Funded design studies in progress, with ESA and national funding
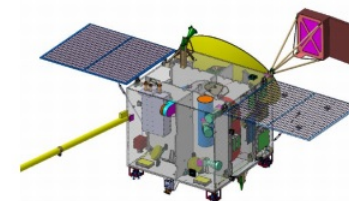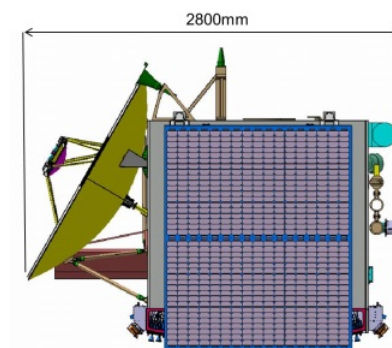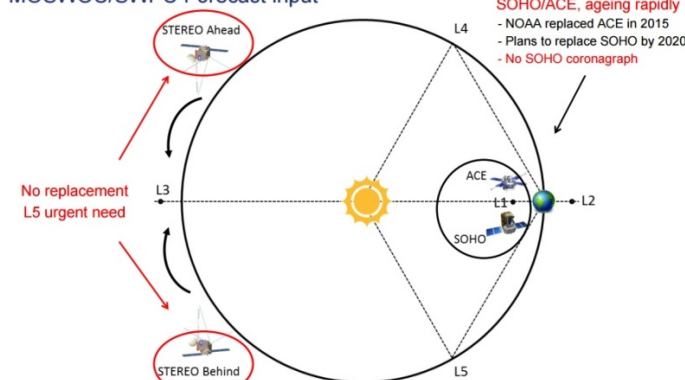
Mission Planning: Solar Orbiter

- Solar Orbiter mission, first ESA M-class for Cosmic Vision

- Launch now October 2018

- Seven year mission

- 60-180 solar radii eccentric orbit

- Involved in build and science planning for SPICE

- High resolution imaging spectrometer at EUV wavelengths

- Will operate as a facility instrument

- Quantify plasma state in outflow and ejection regions

- Temperature, density, flow and composition for plasmas with temperature range 10^4-10^7K
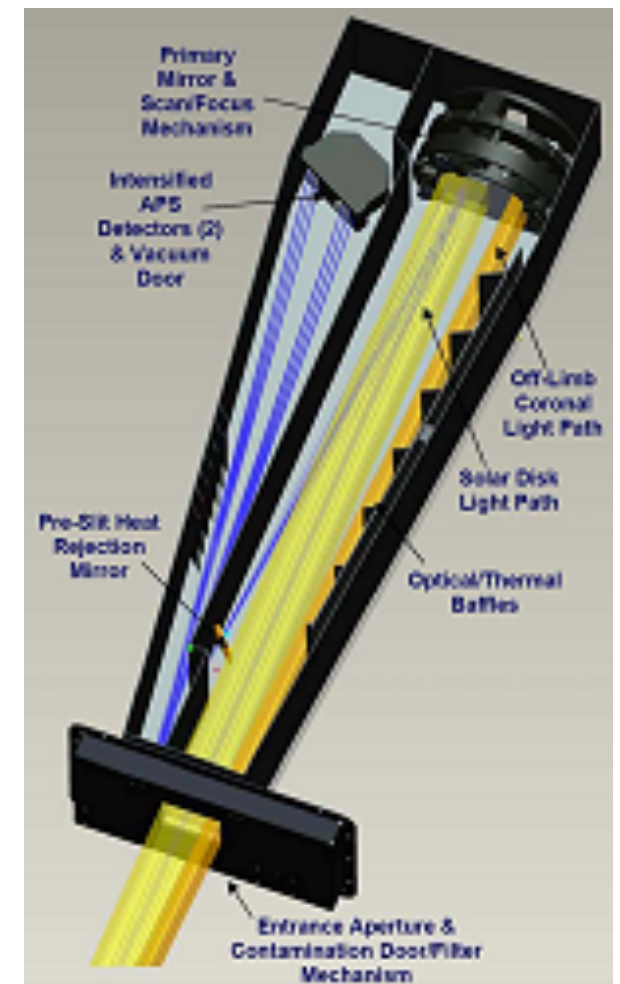
Mission Planning: THOR

- One of three candidate missions for ESA M4

- Swedish-led proposal for Earth orbiter to study small-scale plasma processes

- Heating and energy dissipation in plasma environment, interaction of solar wind with Earth's magnetic field, plasma turbulence (cascade and dissipation)

- Nominal three-year mission with orbit change at end of each year
  - Year 1: Bow shock and magnetosheath
  - Year 2: Solar wind and foreshock
  - Year 3: Solar wind and heliospheric shocks

- Launch 2026 (earliest)

- Our interest in operations planning, data flow, archive
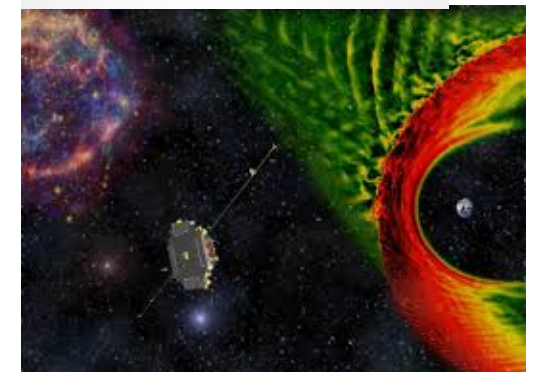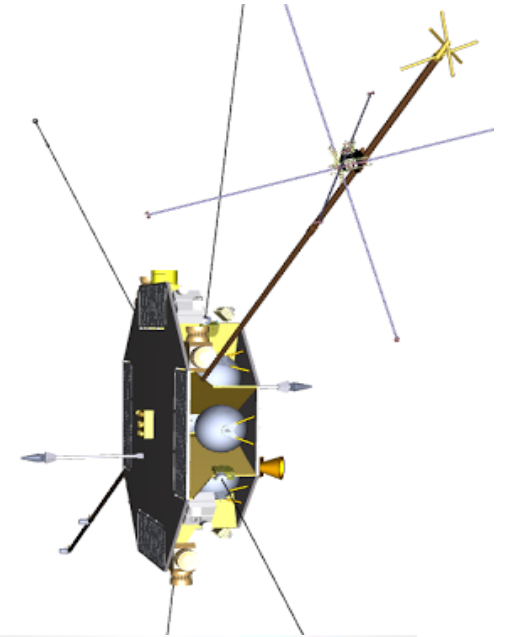
Data Exploitation: HELCATS

- Catalogue transient (CME) and background (CIR/SIR) structures imaged in the heliosphere by STEREO/HI;

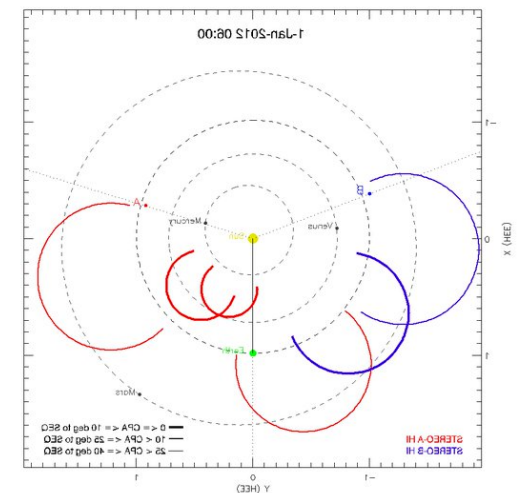- Verify these kinematic properties, by comparing with solar source/coronal observations, and in-situ measurements;

- Assess the potential for initialising models based on the kinematic properties of the transient and background solar wind;

- Assess the complementarity of combining heliospheric imagery with radio-based methods to detect structures and diagnose processes in the heliosphere (IPS and Type II radio bursts);

- Provide the scientific community with easy access to HELCATS catalogues and methodologies.

HELCATS visualization of CME fronts

Data Distribution: UKSSDC, CEDA and JASMIN

UK Solar System Data Centre, intended as the ultimate archive home for all UK solar system data

Covers all ground-based data and space-based data not already managed elsewhere, e.g. in ESA archives

Includes the World Data Centre C1 for Solar-Terrestrial Physics, going back to IGY in 1957, now under ICSU

Operates the two UK ionosondes at Chilton and Port Stanley

Includes a lot of solar data, ISR data….

Joint funding from STFC and NERC

Greater integration with NERC CEDA (Centre for Environmental Data Analysis) and JASMIN supercomputing for environmental data analysis
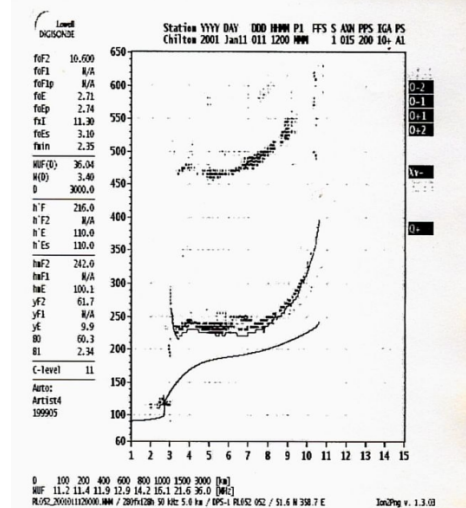
Data Distribution: ESPAS and OpenSpace

Collaboration of RAL Space and Scientific Computing, plus 26 international partners

Development of underpinning infrastructure for access to heterogeneous space weather data

Can also support data access for modelling and predictions (and dissemination of results)

Value added services for data mining and visualisation

>40 data repositories, both ground and space data

Funded by EU FP7: 2011-2016

Now proposing OpenSpace, as a follow-on to bring in the solar community. Under evaluation (H2020)

MOSWOC and BIS

UK National Risk Register 2013/2014
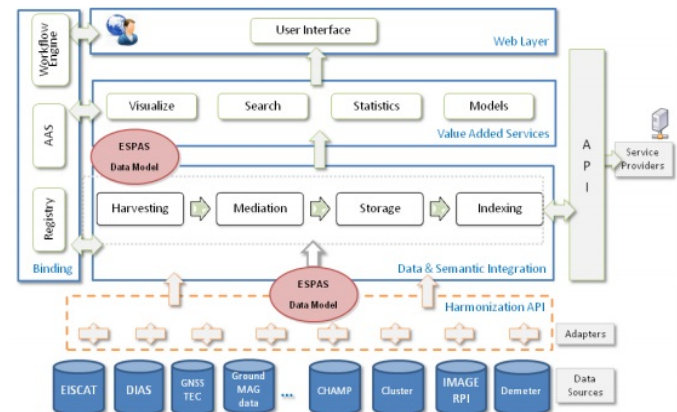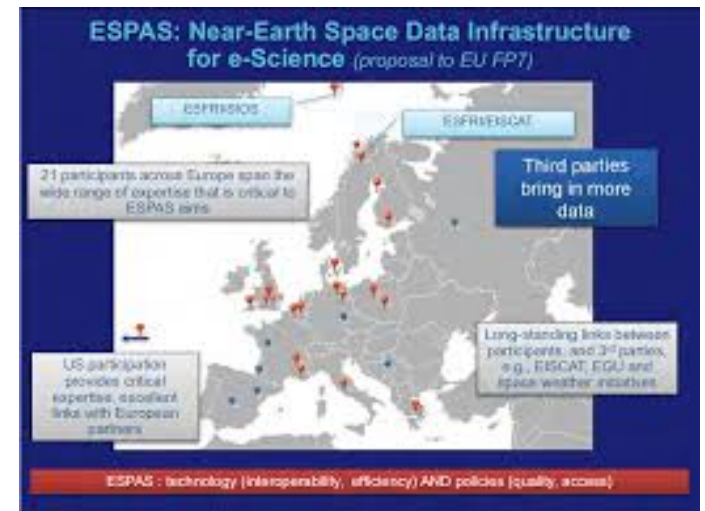
UK Met Office provides the operational capability for space weather prediction in UK

Established after space weather was added to the UK national risk register in 2011

Work closely with Met Office to transfer data, models and knowledge for the operational forecast service (e.g. solar wind propagation and data constraint)

Work with Met Office on a number of future strategic opportunities (L1/L4/L5, SSA Phase 2, preparation for phase 3...)

Other Space Weather Funding

- Internal funding to help us drive the political agenda

- Support for government-level activity
  - SEIEG (Space Environment Impact Assessment Group)
  - Driving forward partnership with BIS and UKMO

- Advocacy for UK involvement in ESA programmes
  - Especially SSA, heading to period 3

- Advocacy for international space weather initiatives

- Public outreach and international collaborative initiatives

ESA Heliospheric ESC

RAL (in partnership with UKMO and others) operates the Heliospheric Expert Service Centre

The newest service centre, beginning 2015
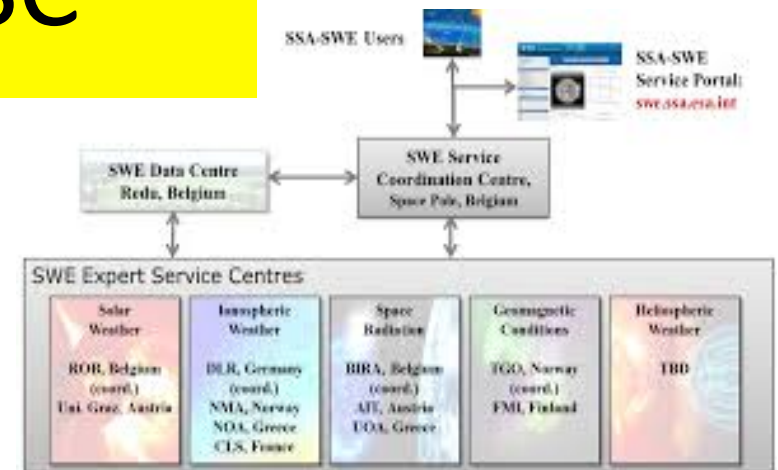
Still currently in set-up phase

Using in-situ and remote sensed observations from various vantage points to predict magnetosphere response to solar wind disturbances

Service providers are: UKMO, Univ. Graz (Austria), DTU (Denmark), IRAP (France)

Consultants: KU Leuven, DH Consulting, Univ. Gottingen (Germany)

Scope to include some of the techniques developed in HELCATS etc.
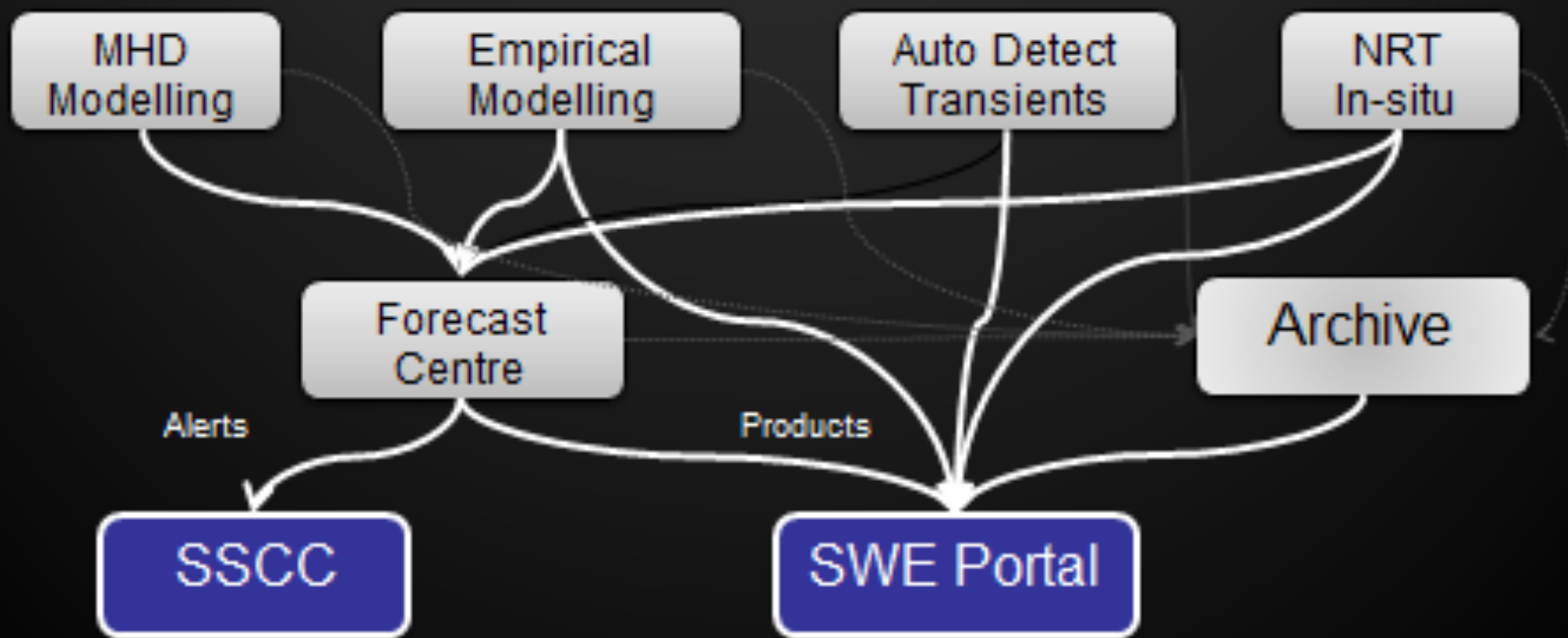
H-ESC Architecture

Solar Magnetogram   Coronagraph   Solar EUV   Near-Earth in-situ

MHD Modelling   Empirical Modelling   Auto Detect Transients   NRT In-situ

Forecast Centre

Archive

Alerts

Products

SSCC

SWE Portal

Forecasting: Sol-Terra project

Funded by UK Space Agency under its General Studies and Technology Programme (GSTP)
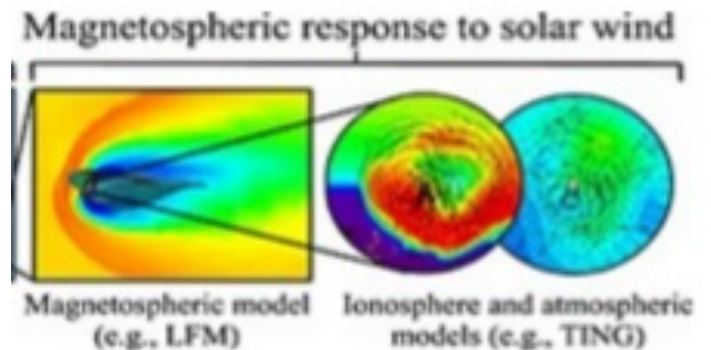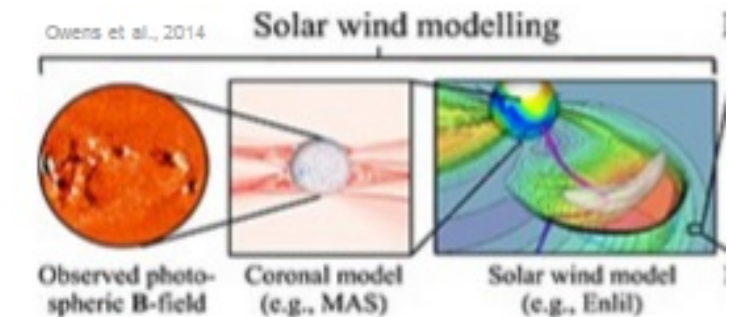
Working with RHEA (UK) and UKMO to find out what models are available globally.

Assessment of:
- Scope and applicability
- Performance
- Validation status
- Quality
- Coupling to other models
- Scope for evolution

Output is specification for roadmap for end-to-end space weather modelling and identification of areas where work is needed

Due to report June 2016

R2O

Improved Science → Research → Operations → Research Impact → Research Funding → Improved Science

Owens et al., 2014   Solar wind modelling

Observed photo-spheric B-field — Coronal model (e.g., MAS) — Solar wind model (e.g., Enlil)

Magnetospheric response to solar wind

Magnetospheric model (e.g., LFM)   Ionosphere and atmospheric models (e.g., TING)

IPSS, EOARD and NASA proposals

Current operation of ENLIL initiallised with WSA

Proposal to investigate possibility to initiallise ENLIL with IPS data at inner boundary (21.5 solar radii)
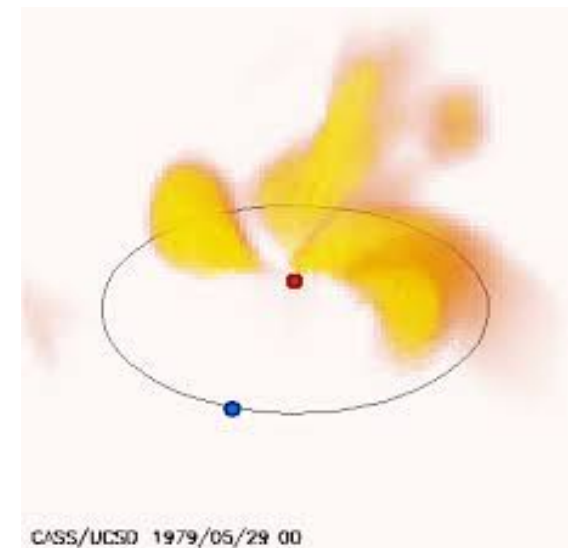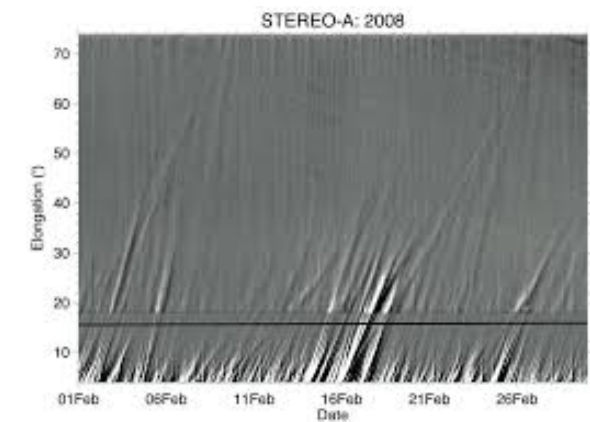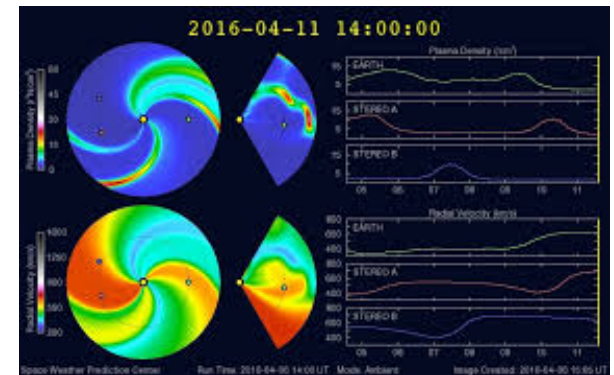
Idea to compare and validate WSA-ENLIL and IPS-ENLIL forecasts

Separate project using LOFAR and other radio data

Investigation of Faraday Rotation techniques in IPS to probe magnetic field structure

Links between CME and magnetic field structure

Consistency between LOFAR results and solar wind tomographic reconstructions
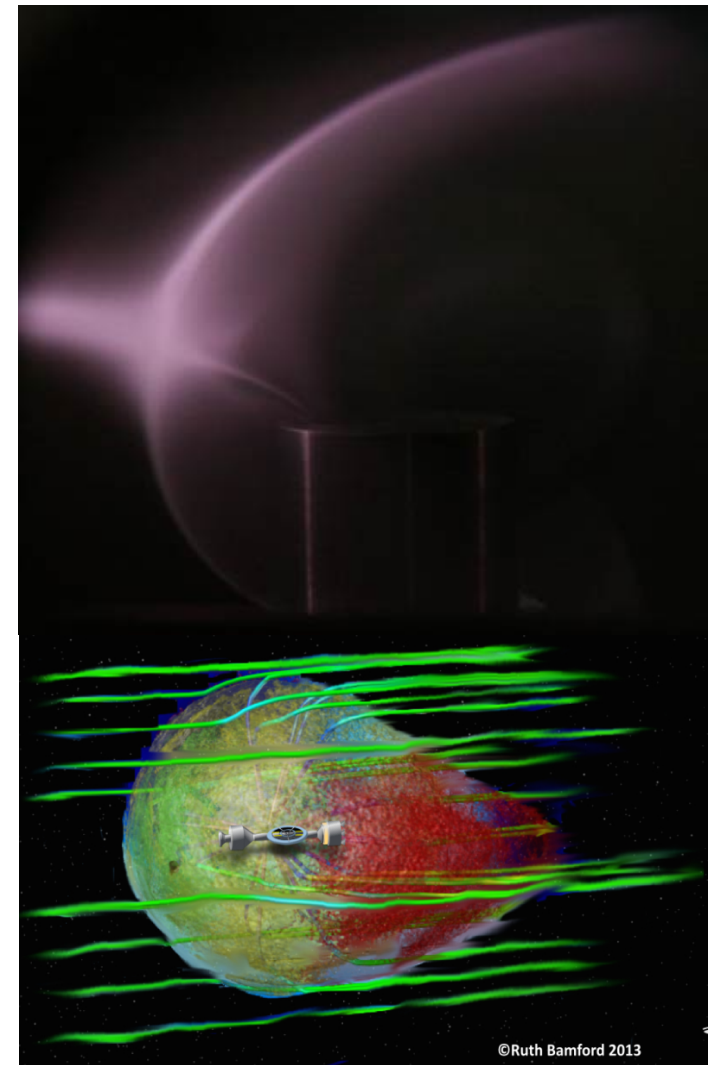
Hybrid and Kinetic Modelling

Various projects on small-scale physics, using hybrid and kinetic codes

Working with Portuguese OSIRIS team (at Instituto Technico Superior, Lisbon)

Mini-magnetospheres: modelling of energetic particle shielding by magnetic field (polarisation field), lab demonstration, application to lunar magnetic anomalies

Surfatron acceleration at shocks as a cause of SEP events

©Ruth Bamford 2013

Simulation ~130 c/w$_{pe}$ Reiner Gamma ~10 km

TIME EVOLUTION

v_y x Phase Space
Time = 0.00 [c/c$_s$ ω_{pio}]

Time = 4.00 [c/c$_s$ ω_{pio}]

Time = 7.00 [c/c$_s$ ω_{pio}]
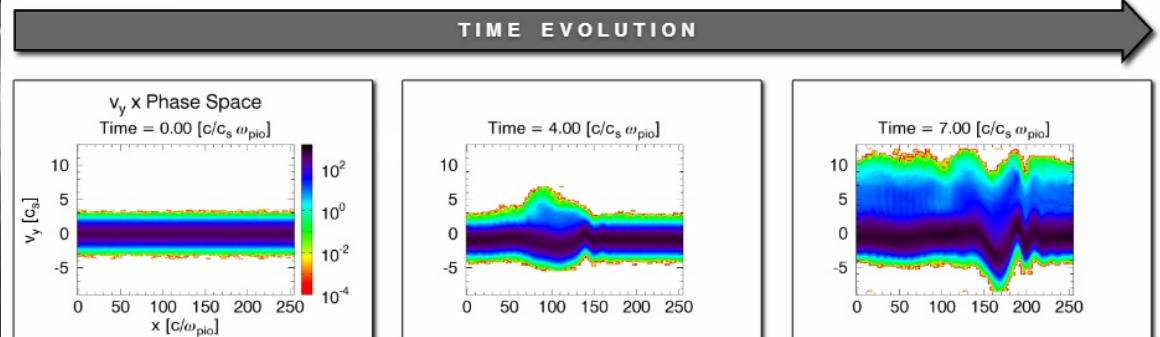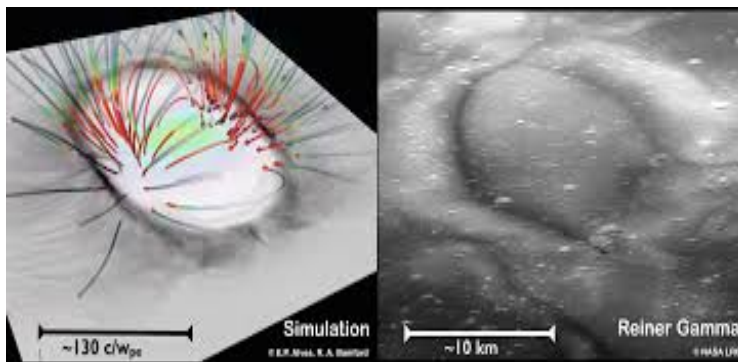
Space Surveillance and Tracking

Programme for evolution of an independent European capability in space surveillance and tracking

Space junk (from LEO to GEO)

2009-2012: Development of a European precursor sensor network

2013-2016: Evaluation of upgrade requirements, actual upgrade programme, development of additional optical and laser sensors, enhancements of databases and IT systems

ESA activity, though largely funded by other EU money

Our interest is development of Chilbolton radar as a LEO sensor, but we also support the overall UK effort (with UKSA and DSTL).

Where are we heading?

- We are a science group. Our aim is enabling SCIENTIFIC PROGRESS and PUBLICATIONS

- Involvement in L5 mission is a major priority for us, though nature of mission not yet defined
  - UK/ESA/US Multi-Lateral

- ESA SSA is a big part of our future programme
  - Space weather mission/instrument studies
  - Expert Service Centre operation and development
  - Participation in SST via Chilbolton Radar

- Upgrade in UK space weather capability
  - Support for development of MOSWOC
  - Support for government space weather policy (BIS/UKCO)

- Development of new capabilities
  - Modelling enhancements
  - New data distribution techniques

Connections to modelling

- Becoming ever more important!

- ESA-SSA is providing European modelling capabilities through ESC system
  - Will develop further in SSA Phase 3

- Interaction with MOSWOC is helping enable a UK space weather prediction capability

- STEREO and HELCATS are providing great data sets for model validation

- Interesting new ideas e.g. on using IPS data in conjunction with ENLIL

- ISR World Day data can be a great modelling resource
  - Connected to the CEDAR challenges

- Looking to smaller scales with hybrid and kinetic modelling